Forest Research at the LFC
1991-1992 Overview

Research Directorate • Quebec Region

Forestry Canada Forêts Canada

Canada

1991-1992 OVERVIEW

FOREST RESEARCH AT THE LFC

FIFTH EDITION

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RESEARCH DIRECTORATE
FORESTRY CANADA, QUEBEC REGION

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INTRODUCTION

To better respond to the many requests for information on its research activities, the Laurentian Forestry Centre has put together this overview of its research projects for 1991-1992.

In the following pages, you will find a complete, up-to-date listing of LFC research projects and their constituent studies. A quick glance will give the reader the titles, key words, and summaries of studies, along with the names of the people in charge of those studies and their associates from outside Forestry Canada. The last section of this overview includes a key-word index referring the reader to studies related to a given subject, as well as a list of abbreviations used and their meaning.

Readers who would like further information may contact the Research Directorate and ask for the person concerned. We can be reached at the following address:

Forestry Canada, Quebec Region
Laurentian Forestry Centre
Research Directorate
1055 du P.E.P.S.
Sainte-Foy, Québec
G1V 4C7
Telephone: (418) 648-7032
Fax: (418) 648-5849

We hope that this outline of our 1991-1992 research activities will prove useful and will direct you, if necessary, to the people who are best able to help: the researchers and their associates.

92-04859/

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CHAPTER ONE

BACKGROUND

The past year has been a very full and active one for the entire Research Directorate. Three new researchers joined Project LFC-45 and worked enthusiastically to develop and computerize our forest insect and disease collections.

We were also pleased to welcome two new technical support staff members in the areas of plant physiology and genetics.

One of our researchers, who had spent a year as senior scientific advisor with Domtar under the STEP program, has returned to our laboratories. His time spent with that company was extremely worthwhile, resulting in the production of a voluminous report entitled "Le phénomène du dépérissement de la forêt feuillue, problématiques et perspectives pour les Products forestiers Domtar".

One of our technicians received six honorable mentions at the 31st North Central Insect Photographic Salon organized by the American Entomological Society.

One of our project managers took on the implementation of the biomonitoring research component under the Canadian Government's Green Plan, while other researchers are acting as regional coordinators for projects under the plan.

This year, several researchers from Europe, Africa, and Asia worked in our facilities. Three of our own researchers were awarded the Forestry Canada Science and Technology Prize.

LFC conferences were more successful than ever, becoming major venues for members of the Québec forestry community. We fully intend to continue these meetings in the years to come in order to give our researchers and their outside colleagues an opportunity to present the latest results of their research to the scientific community.

Several staff members were made associate professors at Université Laval, mainly in the Department of Forestry and Geomatics. This will enable graduate students to pursue their research work in our laboratories at both the master's and doctoral level. In addition, one of our researchers has been awarded the Forestry Canada Deputy Minister's Prize, enabling him to pursue his research in a laboratory in France for several months. This prestigious prize was also won by an LFC technician last year, allowing a working visit to the Polytechnical Institute in Zurich, Switzerland.

As indicated in our 1990 Overview, we continued with the restructuring of our various research projects in order to better

correspond to the Forestry Canada strategic plan both nationally and regionally. In this connection, our main orientations remain:

- to study the effects of biotic and abiotic factors on forest ecosystems and develop means of predicting and mitigating these effects
- to pursue research into pest/host biology and develop biological control strategies
- to promote greater collaboration with universities, industries, and granting agencies
- to develop advanced biotechnological tools
- to pursue our research in certain leading-edge fields with the aim of achieving significant breakthroughs in technology transfer
- to become increasingly involved in the training of high-calibre scientists and technicians
- to expand knowledge of the genetics, growth processes, and productivity of trees and forest stands

In short, the Laurentian Forestry Centre has once again demonstrated that it is a major partner in forestry research in Québec, Canada, and North American.

Director of Research

Michel Boudoux

CHAPTER TWO

RESEARCH

PROJECT LFC-21

POPULATION DYNAMICS

Project LFC-21 is aimed at achieving a better understanding of the population dynamics of spruce budworm. The ability to predict the demographic behavior of this insect under natural conditions or following management procedures is an essential condition for developing decision-making tools to minimize its impact on forest resource availability. Such development should be based on adequate knowledge of the ecological interactions that determine mortality, birth rate, and migration in populations.

More specifically, Project LFC-21 is attempting to identify the mechanisms underlying the development, maintenance, and decline of spruce budworm epidemics. In particular, it is important to (1) properly understand spruce budworm biology in terms of its environment and essential resources (behavioral and physiological), (2) determine the identity, biology, and ecology of natural regulators of spruce budworm populations, and (3) grasp the role of factors that determine their performance.

PROJECT LEADER:	**Jacques Régnière**
SCIENTISTS:	**Johanne Delisle** **Michel Cusson**
TECHNICAL SUPPORT:	**Marc Bolduc** **Pierre Duval** **Pierre Therrien** **Diane Trudel**

Knowledge acquired through this project will first be applied to development and implementation of decision-making criteria for the development and carrying out of spruce budworm control programs in Québec and elsewhere, to include concepts, regulations, and mathematical or simulation models. The research should also make it possible to develop new control methods and strategies based on the use of the natural enemies most likely to control spruce budworm populations. Although development of such control methods goes beyond LFC-21, the results obtained will allow identification of promising organisms to be used as biological insecticides, as well as of empty niches in the life cycle of spruce budworm, thus assisting with research on exotic natural enemies to be introduced and development of forest management plans to reinforce the activity of major natural enemies.

Study LFC-21-01

DYNAMICS OF SPRUCE BUDWORM POPULATIONS

Jacques Régnière

Key words: spruce budworm, natural enemies, natural environment

*

The identity and action of factors responsible for high mortality rates in declining or residual populations of spruce budworm are as yet poorly understood. Among the natural enemies involved at this point of the epidemiological cycle there are promising biological controls (natural pathogens that could be developed as biological insecticides or parasitoids and predators that could be reinforced through species management).By understanding the interactions of its natural enemies with spruce budworm, we may develop forecasting tools and solidly-based silvicultural control approaches.

Photo: Thérèse Arcand

***Anatis mali*, a coccinella predator of spruce budworm**

The specific objectives of this study are (1) to construct survival tables for spruce budworm under a variety of ecological conditions, (2) to observe the activity rate of natural enemies in dwindling populations of spruce budworm, (3) to develop simulation models of spruce budworm population dynamics, and (4) to use the information obtained and the models developed to create decision-making tools for spruce budworm control in Québec.

Outside associates: This project requires the cooperation of the ministère de l'Énergie et des Ressources du Québec (MERQ), which supplies student personnel and considerable data. There is also close cooperation with V. Nealis (Forestry Canada, Ontario Region).

Study LFC-21-02

BIOLOGY AND ECOLOGY OF SPRUCE BUDWORM PARASITOIDS

Jacques Régnière

Key words: spruce budworm, ecology, parasites

*

This study focuses specifically on the biology and ecology of spruce budworm parasitoids which were identified as major elements of the insect's complex of natural enemies under Study LFC-21-01, which provides support and biological material. Aspects studied include (1) life cycle, (2) alternative hosts and their relation to the forest environment, (3) laboratory colonization, and (4) physiological and behavioral studies. Information obtained will help develop biological control strategies aimed at conserving natural populations of these organisms or facilitating their activity by silvicultural or other procedures.

Outside associates: MERQ provides personnel for carrying out this work, notably in the form of financial support to graduate students. J. McNeil and C. Cloutier (Université Laval) act as co-directors for graduate students and V. Nealis (Ontario Region) also participates in certain aspects.

Study LFC-21-03

SPRUCE BUDWORM AND OBLIQUEBANDED LEAFROLLER REPRODUCTION STRATEGIES

Johanne Delisle

Key words: spruce budworm, obliquebanded leafroller, reproduction, pheromones

*

Study 21-03 is designed to obtain detailed knowledge and understanding of the reproductive biology of spruce budworm and, more specifically, sexual pheromone emission and reception behavior, mating and egg-laying in relation to various environmental factors. This basic knowledge will enable us to better define the contribution of adults to the population dynamics of spruce

budworm and also to better interpret the results of sexual trapping as a tool for detection, monitoring, and forecasting of spruce budworm populations.

The influence of temperature, age, food, and the incidence of a pathogen, *Nosema fumiferanae*, are among the factors studied. Similar studies are also being carried out on oblique-banded leafroller, a winter host of a major spruce budworm parasitoid, *Meteorus trachynotus*.

Outside associates: MERQ provides significant technical support for laboratory and field studies.

Study LFC-21-06

SPREAD OF ADULT SPRUCE BUDWORMS

Johanne Delisle

Key words: migration, spruce budworm

*

The spread of adult spruce budworms, more specifically gravid females, is one of the factors responsible for unanticipated changes in the population density of the species. Little is as yet known about factors that promote the movement of budworm moths. This study is aimed at estimating emigration rate in terms of population density and characterizing migrant and non-migrant adults considering various allometric and physiological factors such as size, weight, degree of infection (*Nosema*), and the reproductive state of females. Meteorological data are also recorded hourly during the entire flight period to determine climatic influence. Certain of the above factors will be examined in greater detail as regards adult flight behavior using a flight mechanism appropriate for this type of study.

Outside associates: MERQ provides significant technical support for laboratory and field studies.

Study LFC-21-09

PHYSIOLOGICAL AND BIOCHEMICAL ASPECTS OF INTERACTIONS BETWEEN SPRUCE BUDWORM AND ITS NATURAL ENEMIES AND HOST PLANTS

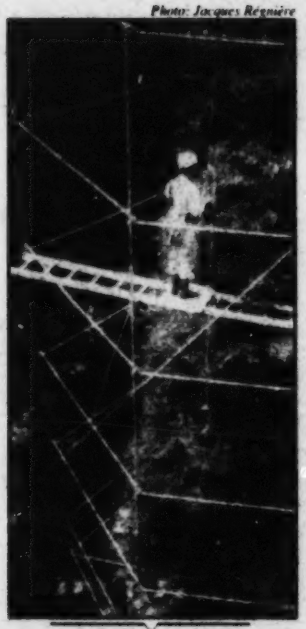
Michel Cusson

Key words: spruce budworm, physiology, biochemistry

*

This study examines the influence of host plant quality on physiological interactions between spruce budworm and some of its natural enemies. These tri-trophic interactions may be of particular importance at the end of phases of spruce budworm epidemics, when good quality foliage starts to become scarce. This is why it is important to initially study a parasitoid, the Hymenoptera *Synetaeris tenuifemur*, significant during the declining phase of spruce budworm epidemics.

Photo: Jacques Régnière



Measurement of avian predation on spruce budworm

PROJECT LFC-24

BIOLOGICAL CONTROL

The overall goal of the project is to develop environmentally-acceptable means of controlling forest pests. The immediate goal is to use biological means to control forest insects and diseases using various techniques for better studying the organisms involved in terms of their ways of acting on the host and its reactions to infection. Specific techniques used include biotechnological techniques such as the production of monoclonal antibodies and molecular probes, development of light or attractant traps to estimate insect populations, parasitoid raising techniques, biochemical and immunological techniques, etc. Another goal is to contribute actively to the training of new researchers and professionals.

PROJECT LEADER:	**Guillemond Ouellette**
SCIENTISTS:	**Luc Jobin** **F. Wolfgang Quednau** **José R. Valéro**
TECHNICAL SUPPORT:	**Charles A. Coulombe** **De Sève Langlois** **Nicole Lecours** **Roger Roy**
GUEST RESEARCHER:	**Michel Nicole**
POSTDOCTORAL FELLOW:	**Danny Rioux**

Study LFC-24-01

DIAGNOSIS OF *GREMMENIELLA ABIETINA* RACES

Guillemond Ouellette

Key words: scleroderris canker (*Gremmeniella abietina*), host/pathogen relationship

*

Gremmeniella abietina

The need persists for a sure and consistent means of identifying the various strains of *G. abietina* var. *abietina*, the pathogen of scleroderris canker. While we must attempt to perfect our methods of electrophoresis identification, we must also (1) analyse DNA patterns for the various races involved to determine whether it is possible to produce specific molecular probes for each strain, and (2) test for different strains using isoenzyme studies.

To this end, we have been working with Louis Bernard, initially during his short stay at LFC in 1989 as an NSERC postdoctoral fellow and now as a research assistant (Department of Forestry and Geomatics, Université Laval) to isolate various types of DNA from a number of cultures of this fungus. The next step will be digesting this DNA with various restriction enzymes to obtain fragmentation patterns and then move towards the introduction of probes using PCRs. Together with M. Lalonde (Université Laval), we have acquired an apparatus for this purpose, through a joint grant from the NSERC.

During a visit to Switzerland, the project head studied isoenzymes to validate the classification recently proposed by Petrini, Laflamme, and Ouellette (1989, 1990). We also carried out preliminary studies using new apparatus and gels to test isoenzymes (system used by J. Beaulieu, LFC Genetics Laboratory) and demonstrated the possibility of successfully completing this isoenzyme study using the latter method.

The development stages of the pathogen in its hosts remain to be determined if we are to truly understand the mechanisms of resistance to this pathogen and obtain a benchmark for selecting the most resistant strains. Artificial inoculation with *Gremmeniella* by Mr. Marosy in Wisconsin (U.S.A.) has now been reproduced by G. Laflamme and his team (LFC), but certain incubation problems have so far prevented consistent reproduction of these inoculations; it is hoped that the acquisition of a new controlled-humidity chamber will enable us to overcome these problems. We will then be able to take all required samples, at appropriate intervals after inoculation, to study the histopathology of this disease using all appropriate markers (polyclonal and monoclonal antibodies already on hand, molecular probes-see below) to localize cells of this pathogen.

Ophiostoma ulmi

Work on this pathogen and on the histopathology of Dutch elm disease is being conducted mainly with graduate students, with the incumbent acting as thesis director or co-director.

One such doctoral thesis deals with comparative observations of pathogen development in host and non-host trees and on different defense reactions of these trees to infection.

Outside associates: M. Dessureault, Y. Piché, L. Bernier, J.-G. Lafontaine (Université Laval); A. Day (University of Western Ontario); C. Breuil (University of British Columbia); O. Petrini (ETH, Zurich).

Photo: Claude Moffet

Microbiological analysis of insects

Study LFC-24-03

BIOTECHNOLOGICAL CHARACTERIZATION OF ENTOMOPATHOGENS AND PHYSIOLOGICAL POTENTIAL OF INSECT PESTS SUBJECT TO VARIOUS PATHOLOGICAL STRESSES

José Valéro

Key words: entomopathology, biotechnology, molecular probes

*

In managing and protecting forests against insect pests, we must develop ways to:

- diagnose the presence or absence of various entomopathogens in these insects
- identify genomic sequences related to the entomopathogenic power of certain micro-organisms, notably *Bacillus thuringiensis* (B.t.) or nuclear polyhedrosis virus (NPV), and therefore related to their abundance and persistence in host populations
- assess the fate of pests as the result of various types of stress such as starvation or the application of biological insecticides

From this perspective, each type of micro-organism has specific molecular characteristics, and each variety of entomopathogen causes particular metabolic problems in host insects. Using the appropriate molecular markers and clinical biochemical techniques, it appears possible to achieve the above objectives.

This method is aimed at developing guidelines for the forecasting and diagnosis of forest insect pests or microbial epizootics in these insects.

Outside associates:
Université Laval, Sainte-Foy, Québec: R. Letarte, Department of Medical Microbiology: development of biotechnology methods for differentiating between entomopathogens and characterizing B.t. plasmids; R. Marin, R. Tanguay, and S. Guérin: isolation of B.t. plasmids, characterization of insertion sequences, and obtention of genomic probes (NPV identification); R. Marin is a trainee at LFC in connection with her graduate studies program at Université Laval; S. Bourque and M. Lavoie: isolation and characterization of B.t. serotypes isolated in forest insects.

Molecular Biology Research Institute, Montréal, Québec: R. Brousseau: genetic engineering of B.t. (plasmids and serotypes).

Private enterprise: Syndicat des producteurs de bois du Saguenay-Lac-Saint-Jean; UPA; and Conseil régional de concertation et de développement du Saguenay-Lac-Saint-Jean.

Pharmaceutical companies, notably: Alcan (Jonquière, Québec); Solvay (Brussels, Belgium); CIL (Montréal, Québec); and Novo (Montréal, Québec, and Copenhagen, Denmark).

Study LFC-24-04/1

WORLD ATLAS OF DREPANOSIPHINE APHIDS (*HOMOPTERA: APHIDOIDAE*)

F. Wolfgang Quedneau

Key words: entomology, taxonomy, *Homoptera: Aphidoidae*

*

An illustrated catalog is needed covering some 500 species of aphids formerly classified as "*Drepanosiphominae*" or "*Drapanosiphinae*". These aphids infest hardwood mainly of the *Fagales* and other families (e.g. *Etulaceae*, *Juglandaceae*, *Ulmaceae*, *Aceraceae*, and *Combretaceae*). This atlas should contain keys to aid identification. To date, many of these species are known by different names in different countries, and their descriptions are scattered throughout the world literature. It would be useful to have all this information condensed into a single volume.

The presentation of the atlas will allow aphids to be identified immediately without having to refer to museum specimens.

Other justifications for this project follow:

- The possibility of accidentally introducing foreign species creates a need for rapid recognition of new species.

Photo: Claude Moffet

Installation of a Multipher trap for budworm detection

- Possible future losses of rare specimens will be avoided by the use of atlas illustrations based on these specimens.

- The workload of museum specialists in identifying these species will be considerably lightened.

- Since many species illustrated in the atlas are indicative of healthy biocenoses and their presence in the environment is beneficial, criteria for distinguishing between these insects will be made available to the general public.

Drepanosiphine aphids are of particular interest since their sub-family status is currently in question. A recent publication by Ramaudière and Stroyan (1984) provides for some 25 sub-families of vivioviparous aphids, and *Drepanosiphinae* should be included as a separate sub-family. Drepanosiphine aphids have occupied a key place in the development of aphids since the Jurassic period, with modern representatives developing from an ancestral form already in existence during the Cretaceous period. Since there is an almost continuous chain of genuses and species in current fauna, the atlas will make it possible to perform computer simulations of phylogenetic lines to predict species not yet discovered.

Study LFC-24-04/2

BIOLOGICAL CONTROL OF THE GYPSY MOTH

F. Wolfgang Quedneau

Key words: entomology, parasitoid, gypsy moth

*

Lymantria dispar has become a major defoliator of hardwoods in Eastern Canada in recent years. Interest in biological control of this insect has increased since large-scale application of other biological treatments such as Dimilin and *Bacillus thuringiensis* is very costly. This study proposes to introduce the most promising entomophagous parasites of gypsy moth. Many owners of hardwood lots, gardens, parks, and recreational areas will benefit from this work.

Outside associates: Part of the work is being carried out in liaison with V. Nealis (Great Lakes Forestry Centre). The CAB International Institute of Biological Control has agreed to send us lots of *C. samarensis* from Switzerland through the Biosystematic Research Institute (Ottawa); M. Sarazin will deal with quarantine requirements.

Study LFC-24-07

DEVELOPMENT OF TRAPS AND METHODS FOR DETECTION AND MONITORING OF FOREST INSECTS

Luc Jobin

Key words: entomology, detection, traps

*

An effective strategy for protecting the forest environment against insect damage should include observation not only of harmful species, but also of a larger array of forest insects in order to minimize the possible negative impact of management or protection activity on this ecosystem. To achieve this, we propose developing traps and techniques for sampling different insect species whose presence and abundance characterize different forest biotopes and which may be used in setting up forest insect pest monitoring networks.

Outside associates:

Ministère des Forêts du Québec (MFO) (Québec's department of forestry): SPIM will participate in the development of forest insect sampling methods in natural forests and plantations.

Université du Québec à Trois-Rivières: Participating in tests with light traps for catching mosquitos.

Study LFC 24-08

INSECT MICROBIOLOGY: THE USE OF MICROBIALS TO COMBAT INSECT PESTS

José Valéro

Key words: entomopathology, biotechnology, virus

*

The use of entomopathogenic micro-organisms against in-

sects is a promising control method, in particular *Bacillus thuringiensis* (B.t.) and various other viruses. These entomopathogens are highly specific, non-polluting, and do not harm the environment. At present, some of these microorganisms may be produced industrially and be used as an alternative to chemical insecticides in our efforts to conserve forest resources and protect nature (air, drinking water, and soil). In this connection, major infestations of spruce budworm (*Choristoneura fumiferana*) have given new priority to research on operational use of B.t. and other baculoviruses against this pest.

The project aims to develop or improve complete application technology for B.t. and various baculoviruses for control of *C. fumiferana* (spruce budworm) and other forest insects, in particular gypsy moth, sawflies (notably *Neodiprion swainei*), and spruce budmoth (*Zeiraphera canadensis*).

Outside associates:
Université Laval, Sainte-Foy, Québec
R. Letarte, Department of Medical Microbiology: evaluation of the safety of using microbial insecticides, notably B.t.; development of biotechnology methods for differentiating between entomopathogens and their action on target insects; development of new biodegradable adhesives to improve the ability of microbial insecticide preparations to stick to targets (possible collaboration with B.Costerton, University of Calgary).

H. Ackerman: electronic microscopy characterization of entomopathogens and various other micro-organisms, in particular bacillus bacteriophages.
Université du Québec à Chicoutimi
R. Côté: development of biodegradable adhesive additives for biopesticides.
Private enterprise
Syndicat des producteurs du bois du Saguenay-Lac-Saint-Jean; Fédération des producteurs de bois du Québec; UPA; and Conseil régional de concertation et de développement du Saguenay-Lac-Saint-Jean: planning an industrial complex for production of biotechnological derivatives, in particular B.t. Various pharmaceutical companies, notably: Alcan (Jonquière, Québec); Solvay (Brussels, Belgium); CIL (Montréal, Québec); and Novo (Montréal, Québec, and Copenhagen, Denmark): development of ultra-concentrated suspensions of B.t. that can be spread in very low volumes per hectare and still deliver the required dose (20-30 x 10^9 I.U./ha).Syndicat des producteurs de bois du Bas-Saint-Laurent: experimental aerial spraying of B.t. 3a3b to protect private woodlots against spruce budworm.

Study LFC-24-11

DEVELOPMENT OF NEW METHODS OF INSECT PEST CONTROL

Luc Jobin

Key words: insects, biological control, *Zeiraphera canadensis*, spruce budworm, NPV

Photo: Roger Roy

Releasing gypsy moth parasitoids

*

The effectiveness of a new entomopathogen, a nuclear polyhedrosis virus (NPV) developed at the LFC, will be tested in 1991, possibly in aerial tests, in stands infested by spruce budworm to determine the effectiveness, persistence, and spread of the virus. The tests will also be used to develop an economical, effective application strategy for this virus. Spruce budworm sexual pheromone and light

traps will be used to measure the spread of NPV by male and female moths that have survived the entomopathogen. Effectiveness of the growth regulator Dimilin will also be tested as a means of protecting plantations against damage by white pine weevil, against which no effective, economic control method has yet been developed.

Outside associates:

MFO

SOPFIM will carry out aerial spraying with NPV and pre- and post-treatment inventories of larva populations and foliage protection. Tests with Dimilin will be carried out in close co-operation with SPIM and the Beauce-Appalachian Management Unit, along with A. Retnakaran (Forest Pest Management Institute).

Université du Québec à Trois-Rivières

Participation in light trap tests for catching mosquitos.

PROJECT LFC-25

PLANTATION MANAGEMENT FOR PEST CONTROL

The main goals of this project are to integrate knowledge and research results on protection into the forest management decision-making process when making choices on plantation location and maintenance. To achieve this, we must identify environmental factors for forecasting the main problems involved in growing and protecting reforested species so as to increase productivity and minimize the amount of management activity required at these sites. A better understanding of the factors governing the behavior of certain pests in plantations will also assist in characterizing high-risk areas for a given species in terms of adverse factors. The project is also aimed at assessing the potential and development of tools (expert systems and geographic information systems) to be used in incorporating research results into plans for establishing and maintaining plantations in Québec.

PROJECT LEADER:	**André Lavallée**
SCIENTISTS:	**Robert Allard** **Louis Archambault** **Gaston Laflamme** **Robert Lavallée**
TECHNICAL SUPPORT:	**Robert Blais** **Luc Côté** **Jacques Morissette**

Collecting blister rust samples from Eastern white pine

Study LFC-25-01

CHARACTERIZATION OF YOUNG WHITE PINE PLANTATIONS IN TERMS OF BLISTER RUST

André Lavallée

Key words: blister rust, Eastern white pine, plantations

*

The study is aimed at improving the quality and quantity of live Eastern white pine stems in plantations by reducing the impact of blister rust and white pine weevil. In future plantations, all information on these enemies must be considered when choosing a site. Our research attempts to identify the risk of attack by these pests based on the location of the plantation to be able to plan any needed silvicultural management from the outset.

In established young plantations, there is not enough information on the behavior of these pests to allow valid forecasting. It is hoped that detailed surveys will enable us to more accurately determine the annual progress of rust and weevils, how quickly they are spreading, and how hosts are responding (survival rates, degree of deformity, etc.) to these attacks.

Outside associates:
The MFO has provided data to be used in determining study sites.

Study LFC-25-02

CHARACTERIZATION OF RED PINE PLANTATIONS IN TERMS OF SCLERODERRIS CANKER

Gaston Laflamme

Key words: red pine, scleroderris canker, jack pine

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Scleroderris canker mainly affects red pine. Measurement of the various environmental parameters encountered in the natural environment is aimed at identifying those that trigger an epiphytotic. This information will enable us to better prevent nursery diseases and improve our plantation control methods.

Testing will confirm which factors trigger epiphytotics. Other species such as jack pine, Scots pine, spruces, balsam fir, and larch will be tested in the same way in order to determine the impact of other fungus varieties or species on these species in plantations.

Outside associates:
MERQ (Ottawa Valley and Québec); Syndicat des producteurs de bois des Groupements forestiers; J. Hudak and G. Warren (Forestry Canada, Newfoundland); M. Karlman (Sweden); U. Heiniger (Birmensdorf, Switzerland); O. and L. Petrini (ETH, Zurich); M. Dessureault and G. Bussières (Université Laval); C. Bordeleau and L.Innes (MERQ).

Study LFC-25-03

PRESCRIPTIONS FOR FIGHTING DISEASE

André Lavallée and Gaston Laflamme

Key words: pathology, endophytes, silviculture, fomes root rot (*Fomes annosus*)

*

A growing number of requests for prescriptions for forest diseases are coming from other LFC projects or outside multidisciplinary groups. Given the small number of forest pathologists available, this study is aimed at giving foresters relevant information to enable them to improve the chances of success in their silvicultural operations. The information requested deals with a variety of subjects and thus requires specific studies on each topic.

Outside associates: Since these problems often fall outside our respective research areas, these topics may be assigned as subjects for master's or doctoral theses to Université Laval students and thus serve as more detailed studies related to current research. M. Dessureault and G. Bussières (Université Laval); M. Grandtner and N. Villeneuve (Université Laval); O. and L. Petrini (ETH, Zurich); G.Martin (University of Wisconsin, U.S.A.); L. Innes and C. Bordeleau (MERQ); Centre de recherche en biologie forestière (CRBF).

Study LFC-25-04

WHITE PINE WEEVIL IN NORWAY SPRUCE PLANTATIONS

Robert Lavallée

Key words: entomology, host/insect relationship, white pine weevil

*

Plantations of Norway spruce (*Picea abies* Karst.) and Eastern white pine (*Pinus strobus* L.) in Québec can provide excellent yields in terms of timber when planted on appropriate sites; however, these two species are facing a major problem, the white pine weevil (*Pisodes strobi* Peck).

In general, all plantations are considered equally vulnerable to white pine weevil. The small amount of information gathered on this insect in the past led us to believe that its attacks concentrated on the fastest-growing trees in a plantation.

Our research has shown that the behavior of this weevil on Norway spruce does not reflect these observations by other entomologists. In a given plantation, all trees are initially vulnerable to attack by the weevil, and not the tallest.

Moreover, the rate at which damage progresses varies from one site to another. In some plantations, this happens faster than in others. So far we have found no explanation for these differences.

It is, however, recognized that drainage is a prime factor both

Photo: Gaston Laflamme

Checking for symptoms of scleroderris canker on red pine

for the growth of host trees and for its indirect effect on phytophagous insects. Our research objectives are to show that there is a link between the hydric stress to a host and the subsequent successful development of weevils under its bark.

Outside associates: P.J. Albert (Concordia University, Montréal); B.S. Mangat (Concordia University, Montréal); Y. Mauffette (UQAM, Montréal); E. Bauce (Faculty of Forestry and Geomatics, Université Laval).

Study LFC-25-05

EXPERT SYSTEMS FOR PEST MANAGEMENT IN PLANTATIONS

Louis Archambault

Key words: GIS, expert systems, plantation, pests, artificial intelligence

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The overall aim of this study is to develop decision-making systems for pest management in plantations. Specific objectives are:

- to develop decision-making systems for choosing reforestation species based on site to maximize production and minimize potential damage by insects or disease
- to develop decision-making systems to diagnose the principal insect and disease problems affecting plantation species in Québec
- to develop decision-making systems to recommend prescriptions in plantations affected by insects or disease
- to develop procedures for integrating expert systems developed in this study into other data and models available in Québec on pest management in plantations.

The systems developed might have one or more sub-systems, i.e.: 1) SIRS sub-system, 2) expert sub-system (ES), 3) database management subsystem (SGBD), 4) statistical analysis sub-system, and 5) modeling sub-system.

Outside associates: Centre d'enseignement et de recherche en foresterie de Sainte-Foy inc. (CERFO); Service de protection contre les insectes et les maladies des arbres (MFO); Faculty of Forestry and Geomatics (Université Laval); Inventory Service (MFO).

GROWTH AND PRODUCTION IN MANAGED FORESTS

Québec's Bill 150 requires that forest management follow the principle of sustained yield in order to guarantee the logging industry a continuous supply of timber. This bill also makes the logging industry responsible for putting cut areas back into production and obtaining optimum yields through appropriate silvicultural methods. In the context of intensive management, the objectives of this project are: (1) to develop techniques and methods for acquiring adequate knowledge of the resource and its yield, (2) to validate hypotheses governing production modeis, (3) to relate stand characteristics and productivity, (4) to further examine the role of growth processes on the development of trees and stands, and (5) to develop the appropriate silvicultural strategies for management series.

PROJECT LEADER:	**Denis Ouellet**
SCIENTISTS:	**Jean-Louis Bélair** **Jacques Tremcia** **Chhun-Huor Ung** **Richard Zarnovican**
TECHNICAL SUPPORT:	**Rhéal Anguru** **Jean-Baptiste Bouza** **Adrien Pangou** **Gérard Lavoie**

Photo: Claude Moffet

Studying the architecture of quality commercial hardwoods

Study LFC-41-01

TIMBER PRODUCTION OF FOREST STANDS

Richard Zarnovican

Key words: yield tables, management framework, tolerant hardwoods

*

This study involves developing and describing the components of a time-space framework for the intensive management of hardwood forests. The study, to be carried out in forest stands in the tolerant hardwood region of Québec, is based on an analysis of the main dendrological and biophysical features.

The primary goal of the study is to determine timber production over time and draw up yield tables related to a given silvicultural practice. This part of the study constitutes the time frame. The spatial element is defined by growth conditions at the regional level and by management series at the local level. Definition of the spatial element is based on an analysis of biophysical factors and on the ecological profile of the region and stand.

Another aim of the study is to develop and test various dendrological methods, techniques, and devices for determining the productivity and growth of trees and forest stands.

Outside associates: Research in the two St. Zacharie stands is being carried out in close cooperation with P. Desrochers, D. Gingras, and M.-A. Gagnon (Domtar Inc). Monitoring of the plantation at Ascot Corner is being done with the help of G. Marcotte (Groupement forestier Saint-François). We are also in contact with Z. Magcen (MERQ).

Study LFC-41-02

EFFECT OF SILVICULTURAL OPERATIONS ON THE ROOT AND AERIAL DEVELOPMENT OF DECIDUOUS SPECIES AT THE SAPLING STAGE

Jacques Trencia

Key words: roots, establishment of stands, deciduous species

*

Experience acquired elsewhere in silvicultural methods on deciduous species for the production of quality assortments demonstrates the prime importance of the establishment phase in stands. It is during the thicket, sapling, and pole stages that it is possible to modify the composition and distribution by stand social class and influence end quality and financial value. In general, deciduous stands in Québec did not in the past receive the required treatment that would have promoted quality production. The Québec Furniture Manufacturers Association has reported the catastrophic state of supply of prestige hardwoods. Correcting this situation will require increased knowledge of the regeneration and maintenance of young stands. The two main solutions for reforestation are planting the missing species in their original stands or allowing the natural regeneration of species already on site. These two strategies are often combined.

The purpose of this study is to increase knowledge of silvicultural methods (for quality production) and of the development processes of juvenile prestige hardwoods. The priority for each species studied is to determine:

- the nature and succession of silvicultural operations
- the relations between the growth and survival of tolerant hardwoods, as well as their morphology and biophysical factors

There is a significant lack of information on the effect of early silvicultural treatments on the aerial and root development of our hardwoods; the main treatments to be studied are regeneration cutting (or cleaning), soil preparation (plowing and harrowing), type of regeneration (seeding or planting), mechanical and chemical vegetation control, and clearing and cleaning.

This study will:

- study and test methods and apparatus for studying root system morphology
- determine the importance (relative or absolute) of the root system of a tree for optimum growth

- characterize growth conditions (particularly soil quality) that promote optimum, balanced development of trees to produce quality assortments.

Outside associates: L. Robitaille, D. Robitaille, and Z. Macjen (MFO); P.Bellefleur (Université Laval); M. Belgrand and E. Dreyer (INRA, Nancy, France).

Study LFC-41-03

TRANSFORMATION OF DETERIORATED STANDS

Chhun-Huor Ung

Key words: silviculture, reforestation under open canopy, transformation of stands

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The purpose of the study is to demonstrate the pertinence of transforming deteriorated forests by thinning, introduction of valuable species into the shelter provided by reserved trees, and progressive regenerative cutting of the replacement stand. The study will determine the influence of the former stand on regeneration (natural or artificial) during the replacement phase (when the two stands co-exist). The goal is to determine to what extent regenerative cutting of varying intensity and number influences the growth and development of regeneration. This information would enable us to determine the ideal rotation between cuts and optimum density of cover during the transformation stage in a stand.

Outside associates: Groupement forestier du JAL.

Study LFC-41-04

ALLOMETRY AND ARCHITECTURAL DEVELOPMENT OF HARDWOODS

Denis Ouellet

Key words: architecture, morphology, morphometry, growth

*

The principal objective is to study the architecture of deciduous species based on their morphological characteristics, their development strategy, and their need for living space for the production of quality assortments. To do this, we must: 1) make an architectural analysis of yellow birch and sugar maple, 2) determine the relationship between the architecture of the species, allometry, and tolerance to shade, 3) assess the effect of light (quantity and quality) on the growth process and the ontogeny of twigs, and 4) establish the effects of the degree of silvicultural practice on the architectural development of the species to control crown development, secondary stem growth, and technological qualities.

Outside associates: An experimental design has been set up in collaboration with L. Robitaille (Research branch, MFO). In 1990, cooperation with the Institut de botanique in Montpellier was intensified for the fundamental aspects of plant architecture. Also in 1990, work carried out in collaboration with P. Bellefleur (Université Laval) enabled us to undertake a study of the effects of light on the architectural development of yellow birch. This research was done in connection with the co-direction of a master's thesis. In 1991, research will be carried out with C. Ansseau (Université de Sherbrooke) to determine the relationship between dieback and its effects on spectral reflectance and the architectural development of sugar maple.

Photo: Denis Ouellet

Producing quality assortments by appropriate silvicultural methods

Study LFC-41-06

GROWTH AND PRODUCTION OF MIXED FORESTS

Richard Zarnovican

Key words: site index, mixed forest

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This study will look at the growth and production of the principal species in the mixed-

forest phytogeographic zone (one of Canada's largest forest areas): white birch, trembling aspen, and jack pine.

The study is based on analysis of the main dendrological biophysical features, and is being carried out in various forest stands in this phytogeographic zone of Québec. The study is intended to determine the timber yield and station quality of stands based on the analysis of stems and of forest structure.

Outside associates: Work on the productivity of black spruce and jack pine stands at Lebel-sur-Quévillon and Dolbeau is being carried on in collaboration with Domtar. Study of the productivity of trembling aspen and jack pine in the Lake Duparquet area is being performed in collaboration with Y. Bergeron (UQAM).

Study LFC-41-08

INVENTORY METHODS FOR ESTIMATING THE GROWTH OF FOREST STANDS

Chhun-Huor Ung

Key words: forest growth, inventory, volume tables, yield tables

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The objective of this study is to develop sampling and field data collection methods and techniques for establishing volume and yield tables. Research looks at unmanaged forests on a regional scale and at managed forests on a local scale.

Outside associates: Groupement forestier du Témiscouata; Domtar; MFO; Université Laval. For managed stands, co-direction of a master's thesis at Université Laval continues. The Groupement forestier du Témiscouata continues to provide support as well. For unmanaged stands, collaboration has commenced with the MFO, the logging industry, and Université Laval.

Study LFC-41-09

FOREST EVAPOTRANSPIRATION

Jean-Louis Bélair

Key words: evapotranspiration, model, hydrodynamics, water balance

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Evapotranspiration is one of the major factors that must be understood in order to assess the growth of trees in terms of site quality, and there is a lack of such studies in Québec.

Where there is no ditch drainage, evapotranspiration is the most important contributor to lowering the water table in poorly-drained soils. When combined with ditch drainage, it becomes the main factor causing stressed water contact to vary. On poorly-drained soil, once water is under stress due to drainage, we have a situation similar to that of well-drained soil but with a greater probability of not having a water deficit because of the boggy environment. Once models have been established, we will be able to use them on well-

drained soils and validate them using the water balance of watersheds (Montmorency Forest would be a good location for such measurements, since the infrastructure is already established).

The drained site at St. Anaclet is a site that would be ideal for the first part of the study, since the substrate, being made of clay, is completely impermeable, with a watershed marked off by a network of drainage ditches. The water balance method can be used on such a site and, with moisture that probably never goes below the critical point (i.e. when the water stress is such that growth ceases without affecting the survival of the tree, a point that occurs between the field capacity and the wilting point, a Wp of approximately 2.0), we will be in a position to determine evapotranspiration during the growing season.

Outside associates: Université Laval.

PROJECT LFC-42

DIGITAL PROCESSING OF SATELLITE REMOTE SENSING DATA

Digital remote sensing is a rapidly developing field, following progress in the areas of electronics and computer processing. Aerial photography will be replaced by digital data from airborne or satellite sensors. The objective of this project is to develop and perfect digital processing methods to make these remote sensing data an operating tool that can meet the current needs of forest inventory and vegetation mapping in general. This will be done for two types of digital imaging, each of which presents a different challenge: satellite (42-04) and airborne (42-05).

PROJECT LEADER:	**Jean Beaubien**
TECHNICAL SUPPORT:	**Guy Simard**

Study LFC-42-04

DIGITAL PROCESSING OF SATELLITE REMOTE SENSING DATA FOR MAPPING FOREST VEGETATION COVER

Jean Beaubien

Key words: remote sensing, satellite, forest inventory, mapping

*

Satellite remote sensing is a constantly developing field. In addition to the well-known American satellites (MSS, 80 m resolution and four spectral bands; TM, 3 m and seven spectral bands; NOAA (AVHRR), 1.1 km resolution for global observations) and SPOT French satellites (20 and 10 multispectral and panchromatic), we now have the Japanese MOS satellites that provide images with resolutions ranging from 50 m to 3.3 km.

Our primary objective is to develop and perfect operational digital processing methods to adapt satellite data to forest inventories and, more generally, to vegetation mapping. We want to develop methods that are simple to use and can therefore be easily transferred to users. They must also be reliable and applicable to different types of vegetation cover based on data collected at different dates and under varying atmospheric conditions.

Digital processing of a satellite image

Outside associates: J. Cihlar (Canadian Centre for Remote Sensing); CARTEL, Université

de Sherbrooke; A. Royer (Octographe inc); H. Audet.

Study LFC-42-05

DIGITAL PROCESSING OF AIRBORNE REMOTE SENSING DATA FOR MAPPING FOREST VEGETATION COVER

Jean Beaubien

Key words: remote sensing, airborne sensors, forest inventory, GIS, MEIS

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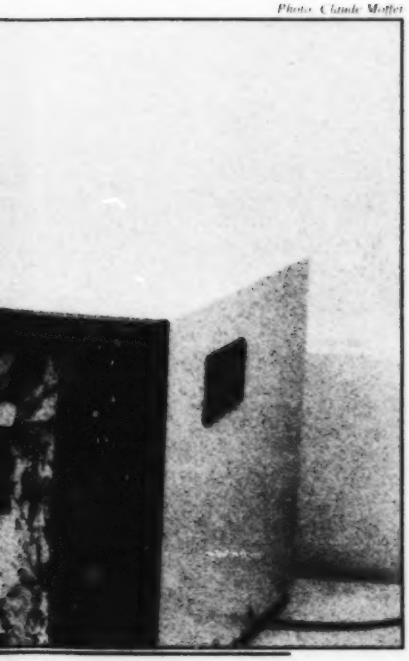
Photo: Claude Moffet



Remote sensing by satellite meets the needs of summary mapping. The low resolution of data does not allow the level of detail foresters require for intensive forest management.

Over the past few years, the Canadian Centre for Remote Sensing has been perfecting airborne digital sensors, in particular the MEIS, a multispectral, electro-optic sensor. These sensors make it possible to obtain high-resolution images in a digital form that provides much greater analysis flexibility than aerial photographs and facilitates their integration into spatial reference systems (SIRS, GIS). Further research and development is still needed to render this technique operational, particularly for forestry. This study is intended to develop and perfect digital processing methods for data obtained from airborne sensors and used in forest cover inventories. The main objectives are:

- choosing spectral bands
- determining spatial resolution
- studying radiometric and geometric corrections to be made to original data
- developing digital image processing methods to obtain optimum interpretive documents
- studying the potential of stereoscopic pairs
- validating results by practicing foresters in the public and private sectors

Outside associates: D. Leckie (Petawawa National Forestry Institute); J. Cihlar (Canadian Centre for Remote Sensing); L. Carrier (Research branch, MERQ); H. Audet (Octographe inc.).

PROJECT LFC-43

GENETICS AND FOREST TREE IMPROVEMENT

The first objective of this project is to attempt to define the population structure of commercial species in Québec so that several other studies may be conducted. These studies are aimed at determining the nature and extent of the genetic variability of the principal coniferous forest species, creating improved synthetic varieties through the identification, selection, and hybridization of superior genotypes and populations, and refining forest tree breeding techniques for maximization of commercial yields.

A special facet of the study is devoted specifically to the transfer of technology and stock of proven and improved genetic quality to users.

PROJECT LEADER:	**Ariane Plourde**
SCIENTISTS:	**Jean Beaulieu** **Gaétan Daoust** **Marie Deslauriers**
TECHNICAL SUPPORT:	**Julie Dubé** **Serge Légaré** **René Paquet**
POSTDOCTORAL FELLOW:	**Mireille Desponts**

Study LFC-43-01

PROPAGATION AND TRANSFER OF IMPROVED GENETIC MATERIAL

Gaétan Daoust and Jean Beaulieu

Key words: propagation, improved genetic material, flower induction

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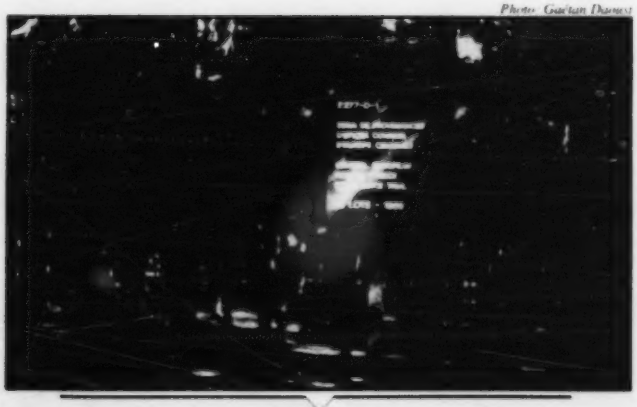
Any integrated research program in forest genetics and tree improvement is a long-term undertaking. Given the longevity and reproductive cycle of woody species, we will nevertheless acquire new knowledge about the variability of species and identify or develop genetically superior stocks at various stages of the program.



Test on Norway spruce at the Valcartier Forestry Station

It is essential that the information thus acquired be used in guiding harvesting and allocation of forest seed stocks, and also that the material improved or identified as genetically superior be used as quickly as possible in hybridization programs to speed up the anticipated genetic gains. We must propagate this material, see that it develops, and make it available for various project purposes.

At present, plant propagation and flower induction techniques are changing rapidly, given the varied needs of users and their different goals. This development must be closely followed to study these new techniques and adapt them in order to take advantage of them to the fullest.

The objectives of this study are:

- to perfect propagation methods for species being studied under the Genetics and Forest Tree Improvement project
- to propagate and oversee the development of genotypes to form the gene base needed to pursue our research and improvement work
- to produce wood material in nurseries (seeds, cuttings, and grafts) for the purpose of tests undertaken in connection with various studies under this project
- to improve flower induction techniques to stimulate flowering on ramets used in improvement programs under this project and thus obtain faster results from cross-breeding plans.

Outside associates: Y. Lamontagne (Tree Improvement Service, MERQ).

Study LFC-43-02

GENETIC STRUCTURE OF NATURAL POPULATIONS

Jean Beaulieu and Ariane Plourde

Key words: electrophoresis, selection, polymorphism

*

In natural populations of living organisms, the range of genetic diversity is determined by concurrent or antagonistic forces, mainly mutation, recombination, natural selection, gene flow, and random genetic derivation. Specific environmental conditions may also play a significant role in certain cases by causing disturbances that alter the spatial uniformity of populations. Depending on the more or less dominant role played by one or more of the above elements, natural populations may exhibit greater or lesser genetic differentiation which may be observed at both the molecular and morphological levels.

It is essential that we have an adequate understanding of the genetic variability in natural populations and of the mating systems used by a given species if we are to optimize selection and inter and intra-population hybridization programs to develop improved synthetic varieties.

The objectives of this study, while corresponding to the strategic development of the research project, will also enable us to optimize the genetic improvement programs set up

by Forestry Canada, Quebec Region.

These objectives are:

- to study the genetic variability of species covered by Project LFC-43 and identify populations and individuals with the required characteristics
- to study the genetic structure of natural populations and mating systems using biochemical markers
- to assess the importance of inbreeding in natural populations and its impact on the assessment of genetic components
- to develop effective strategies for improving forest species

Outside associates:
Over the years, close cooperation has been established with L. Lamontagne, F.Eng., a member of the federal soils study team for the characterization of sites for genecological testing, and with Y. Lamontagne, F. Eng., M. Villeneuve, F. Eng., and A. Rainville, F. Eng., of the MFO Tree Improvement Service regarding implementation of experimental procedures and improvement strategies. J.-P. Simon, P. Legendre, and P.-P. Harper (Université de Montréal) supervise the training in population genetics of the study leader.

Study LFC-43-03

GENETICS OF THE NORWAY SPRUCE

Gaétan Daoust and Ariane Plourde

Key words: genetic improvement, exotic, white pine weevil (*Pissodes strobi*)

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Norway spruce is one of the most promising exotics in southern Québec for the production of both pulp wood and lumber. When planted on appropriate sites, its yield is superior to that of native spruces.

The annual reforestation objective of the MERQ for Norway spruce is in the order of ten million plants. In order of importance, this species ranks fourth behind black spruce, jack pine, and white spruce. To meet its need for seeds, the MERQ is setting up six seed orchards. It has also begun a program of mass selection and mini-cuttings for multiclonal varieties. The use of improved genetic stocks is of prime importance if we are to obtain the greatest yield from future plantations. Development of synthetic varieties is unquestionably the best approach for achieving this, and more in-depth knowledge of the genetics of this species is therefore essential.

The objectives of this study are:

- to define the genetic components and heritability of growth, form, wood quality, weevil tolerance, and adaptability characteristics of this species in Québec
- to identify the most promising gene pools
- to assess the importance of genotype/environment interactions at both the phenological and growth levels
- to identify flower induction treatments that will enable us to influence growth.

Outside associates:
Following discussions between the LFC and the MERQ Tree Improvement Service regarding integration of the research and production components of the overall genetic improvement program for forest trees in Québec, it was agreed that Forestry Canada, Quebec Region, would take responsibility for research on the genetics of Norway spruce, while A. Stipanicic of the SAA would deal with improvement. Forestry Canada, Quebec Region, will also coordinate the integrated research program on the genetics and improvement of this species in Québec.

Study LFC-43-05

GENETICS AND IMPROVEMENT OF WHITE SPRUCE

Jean Beaulieu and Gaétan Daoust

Key words: genetic improvement, white spruce, heritability, wood quality, *Picea glauca*

*

To remedy the insufficient natural regeneration of valuable commercial species after logging and/or forest fires, and to maintain timber potential, the Québec government is carrying out a vast reforestation program. The overall objective is to plant some 230 million seedlings a year. Twenty percent of this stock is made up of white spruce (*Picea glauca* [Moench] Voss). Three hundred hectares of first-generation seed orchards will be planted to produce the required seed. The use of genetically-superior seeds will enable us to increase the productivity and quality of commercial plantations, but only further knowledge of the genetics of this species will help develop improvement strategies that will result in the desired genetic and economic gains.

The objectives of this study are:

- to acquire in-depth knowledge of the genetic components of white spruce and the heritability of its economically-beneficial characteristics
- to define the structure of populations
- to determine the effect and scope of genotype/environment interactions
- to develop synthetic varieties with improved adaptability, productivity, and wood quality characteristics
- to promote the use of genetically-improved stocks

Outside associates:
As the result of agreements between Forestry Canada, Quebec Region, and the MERQ on the integration of the research and production components of genetic improvement programs for forest trees in Québec, a number of their sectors of activity, including genetic sampling of populations, selection and vegetative propagation of plus trees, conducting of descendence tests, and establishment of seed orchards, will be carried out in cooperation with us. We also receive close cooperation from J. Bousquet (Université Laval).

Study LFC-43-06

GENETICS AND IMPROVEMENT OF EASTERN WHITE PINE

Ariane Plourde and Gaétan Daoust

Key words: genetic improvement, Eastern white pine, genecology, white pine weevil (*Pissodes strobi*)

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Eastern white pine (*Pinus strobus* L.) is a sought-after species because of the inherent characteristics of its wood. It should be extensively used in reforestation because of its rapid growth and ability to grow on a wide range of sites, but this is unfortunately not the case. Damage to young plantations by white pine blister rust and white pine weevil has frightened reforesters and resulted in this species being almost completed excluded from reforestation programs between the 1950s and the 1980s. Fortunately, better knowledge of adverse biotic factors and a more rational assessment of the damage they cause have reawakened interest in this species. The annual objective for white pine reforestation is now 4.3 million in Québec alone. This volume justifies genetic improvement of the growth and resistance characteristics of the species. Its phenotype variability indicates the potential of gains through selection and intra-species hybridization, while inter-species hybridization raises hopes for improved resistance to *Chronartium ribicola* J.C.Fish.

The main goals of this study are:

- to acquire more in-depth knowledge of the genetics of Eastern white pine so as to efficiently direct its improvement
- to develop improved synthetic species through intra- and inter-species hybridization
- to identify silvicultural treatments to enable improved stocks to reach full growth potential

Outside associates:
As the result of agreements between Forestry Canada, Quebec Region, and officials at the Tree Improvement Service of MERQ on the integration of the research and production components of the overall genetic improvement

program for forest trees in Québec, a number of their sectors of activity, including genetic sampling of populations, selection and vegetative propagation of plus trees, conduct of descendence tests, and establishment of seed orchards, will be carried out in cooperation with us.

Study LFC-43-07

IN VITRO CULTURE OF PINES

Ariane Plourde

Key words: *in vitro* culture, Eastern white pine (*Pinus strobus* L.), transfer of resistant genes, blister rust (*Cronartium ribicola* J.C. Fish)

*

White pine blister rust is a major fungus disease in Eastern white pine *Pinus strobus* L. Although this is an excellent species for cabinet-making and of high commercial value, it is rarely chosen by foresters when establishing plantations because of its sensitivity to blister rust. Resistance to this disease is therefore a significant component of any white pine improvement program. The small number of sources of resistance to this disease inherent to the species leads us to envisage interspecific transfer of genes resistant to blister rust from other species of pine to *P. strobus*. However, interspecific hybridization normally involves several problems, which can be avoided using *in vitro* culture techniques such as recovery of zygotic embryos and protoplasmic fusion. The hybrids thus produced could be multiplied *in vitro* through somatic embryogenesis and selected *in vitro* for resistance to white pine blister rust.Somatic embryogenesis is also the means of vegetative multiplication of superior genetic material with the greatest potential, both in terms of the number of clones produced and for the genetic stability of the material regenerated. Although these biotechnology techniques have made it possible to achieve such objectives for agricultural species such as wheat, work still remains to be done on adapting these methods to conifers and, in particular, to Eastern white pine.

Photo: Claude Moffet

Controlled cross-breeding of white spruce

The principal objectives of this study are:

- to develop methods of *in vitro* culture of zygotic embryos derived from interspecific hybridization between *P. strobus* and pine species resistant to blister rust
- to study the genetics of resistance to white pine blister rust and identify in haploxylon sub-genuses of pine one or more resistance genes that could be transferred to *P. strobus*
- to assess the possibility of *in vitro* selection for resistance to blister rust
- to develop isolation, fusion, and culture methods for pine protoplasts for the transfer by somatic hybridization of genes resistant to blister rust

- to develop *in vitro* culture methods for white pine to allow multiplication of selected trees of all ages by somatic embryogenesis

Outside associates: Biochemical analyses are being carried out in collaboration with P. Nadeau (Agriculture Canada, Sainte-Foy, Québec).

PROJECT LFC-44

PHYSIOLOGY OF CONTAINERIZED SEEDLINGS AND THEIR PERFORMANCE AFTER OUTPLANTING

This project is aimed at determining silvicultural conditions which modify the type of plants cultivated and studying the relationships between these different types of plants and their behavior in the field.

Previous work enabled us to identify the base conditions for containerized culture of conifer plants. It has been known for some time that morphological variables reveal only one dimension of the plant, and physiological activity might perhaps be included among the characteristics of plants for reforestation. It is essential that we study the conditions that influence these characteristics, establish relations between the morphological and physiological variables of plants produced, and even study their influence on the behavior of planted material.

PROJECT LEADER:	[illegible]
SCIENTISTS:	[illegible]
TECHNICAL SUPPORT:	[illegible]

Comparative plantations have enabled us to assess the survival and growth of planted material. More recent experience has provided information on constraints encountered after planting and have enabled us to propose new characteristics for the plants to be produced or appropriate treatments for reforestation sites.

This information will then be forwarded to the forest nursery as a guide to silviculture management and even to reforesters to enable them to make wise choices about planting material and conditions.

Study LFC-44-01

GROWTH AND PHYSIOLOGY OF SPRUCE SEEDLINGS

André L. D'Aoust

Key words: dormancy, photoperiod, physiology

*

The objective of this study is to identify factors that modify the physiology of seedlings and their subsequent growth in the field.

The physiological quality of plants is a subject on which little information is currently available, and yet this knowledge is necessary for both producers and reforesters.

One aspect that has attracted our attention is the establishment of plant dormancy and its relationship with various growing conditions, as well as with other variables of the plant produced, along with plant tolerance to environmental stress.

Photo: Claude Moffet

Plantation monitoring

Outside associates:
R. Gohier (Centre de production de plants forestiers de Québec inc., CPPFQ); C.-G. Langlois (Seeds, Cuttings, and Grafts Division, Research, and Development branch, MERQ); M. Poirier (Centre sylvicole Forestville inc.).

Study LFC-44-02

NUTRITION AND PEAT PROPERTIES AS SEEDLING GROWTH FACTORS

Antonio Gonzalez

Key words: groundwater, substrate, black spruce, peat

*

This study is aimed at establishing the relationship between the aerial and root biomass of seedlings and other factors such as:

- mineral nutrition and heat sum (black spruce)
- physical properties of the substrate: grain size and water retention capacity of peat (black spruce and white spruce).

Study LFC-44-03

FOLLOW-UP OF EXPERIMENTAL PLANTATIONS OF CONTAINERIZED SEEDLINGS

Claude Delisle

Key words: reforestation, survival, growth, ecoclimatic factors

*

This study has two purposes. The first is to assess the influence of ecoclimatic factors on the growth and survival of containerized seedlings for experimental plantations, and the second is to establish any connection that may exist between the morphological and physiological characteristics of seedlings at the time of delivery to the field and their potential for survival and growth after outplanting.

Study LFC 44-04

MORPHOLOGY AND PHYSIOLOGY OF THE ROOT SYSTEM OF CONTAINERIZED SEEDLINGS

Ronald Girouard

Key words: containerized seedlings, root systems

*

The main objective of this study is to reduce, if not eliminate, in the short and long term, the detrimental effects of various factors, whether physical (the rigid walls of containers), biological (seasonal variations in the growth capacity of roots), or cultivation-related (growing period in containers) on the root development of containerized seedlings.

Outside associates: G. Sheedy (Research branch, MFO); J. Savard (Forest Regeneration Service, MFO); C. Desbiens (Region 01, Management Unit 11, MFO); A. Monfet (Region 04, Management Unit 41, MFO); D.Dubé, D. Jackson,

and R.Rompré (Region 04, Management Unit 42, MFO).

Study LFC-44-07

FROST HARDENING PHYSIOLOGICAL PROCESSES

Francine Bigras

Key words: reforestation, frost, nursery production

*

This study is aimed at controlling the conditions of frost hardening of plants in order to prevent them from unhardening too early in the spring.

We study hardening in the fall and unhardening in the spring in order to determine the relationship between the two processes. To fundamental experiments on hardening and unhardening (photoperiod, temperature) will be added other experiments on the influence of cultivation methods (mineral nutrition, winter cover, production area) on hardening and unhardening. This study is needed because fall and spring frosts cause major losses during the growing of containerized conifer seedlings. Frost damage also occurs in the natural environment following plantation. Spring frosts have been particularly devastating in recent years.

Outside associates:
C.-G. Langlois and G. Lambany (MFO); Centre de production des plants forestiers de Québec inc., CPPFQ; Richard Denis & Associés; H. Margolis (Department of Forestry and Geomatics, Université Laval); J.-A. Rioux (Department of Agriculture, Université Laval).

Study LFC-44-08

SURVIVAL AND GROWTH OF PLANTED SEEDLINGS ACCORDING TO HYDRIC RELATIONS

Pierre Y. Bernier

Key words: reforestation, hydric relation, microclimate

*

Reforestation with nursery plants is an ideal silvicultural method for achieving two high-priority objectives in Canada's forestry industry. The first is to put back into production considerable areas where natural regeneration has failed. The second is the genetic improvement of forests. The costs related to reforestation are considerable and may be increased by problems in acclimatizing plants to field conditions.

The term "plantation shock" designates the interruption in growth and other symptoms that appear when the seedling is planted. Plantation shock causes a direct increase in reforestation costs when areas with dead trees must be replanted. It also increases costs indirectly by prolonging rotation due to plant stagnation. One of the probable causes of this shock is the difficulty the plant has in establishing good root contact with the surrounding soil. Previous studies on the hydric relations of newly-planted trees have shown that all plants undergo hydric stress.

This study is aimed at quantifying the impact of abiotic stress due to site or climate characteristics on the behavior of plants both naturally growing and planted. Through a better understanding of the constraints to which plants are subject as well as better knowledge of the possibilities of the plants themselves, we will be able to optimize both site preparation and the characteristics of plants to be produced.

Photo: Claude Moffet

Seedling measurement

Outside associates:
Outside collaboration for this study is currently confined to that from the MFO and nursery operators for supply of plants, as well as the Leduc sawmill for the loan of a site for field research. M. Lamhamedi is completing his doctorate (under A. Fortin) on the intraspecific variability of *Pisolithus* sp. in its influence on resistance to hydric stress in its host, Maritime pine (*P. pinaster*). A. Zine El Abidine has started his doctorate (co-directed by A.Plamondon) on modeling hydric stress in black spruce plants.

Study LFC-44-10

CONTROL OF COMPETITIVE VEGETATION IN PLANTATIONS USING COMPANION PLANTS

Claude Delisle

Key words: plant competition, plant substitution, leguminous plants, spruce

*

The objectives are:

- to attempt to inhibit the development of adventitious vegetation through an appropriate choice of agricultural varieties, in order to ensure replanted trees optimum survival rates and growth
- to reduce the use of pesticides
- to reduce plantation maintenance costs

Outside associates:
C. Lemieux (Agriculture Canada, Sainte-Foy); S. Dionne, for the loan of land at Sacré-Coeur-de-Rimouski.

PROJECT LFC-45

EFFECTS OF ENVIRONMENTAL STRESS ON FORESTS

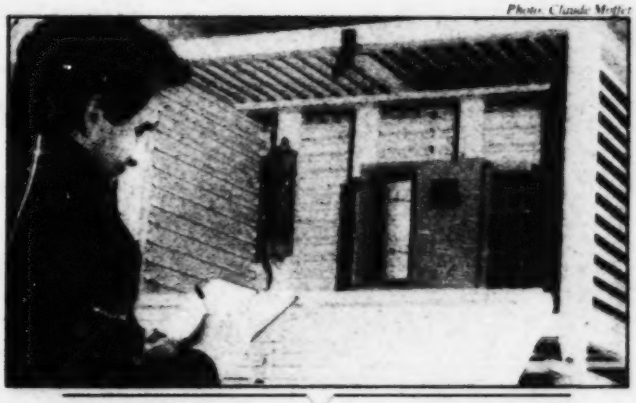
This project was set up to annually assess the status of forest insects and diseases in Québec.

The project involves determining, assessing, and monitoring changes in the health and general growth of several forest stands in Québec, based on environmental factors such as insects, disease, air pollution, and climate changes.

Research will be done on the effects of various atmospheric pollutants and extreme climate factors on forest health.

PROJECT LEADER:	**Denis Lachance**
SCIENTISTS:	**Robert Boutin** **Pierre DesRochers** **Christian Hébert** **Gilles Robitaille** **René Cauchon***
CHEMIST:	**Alain Le Page**
TECHNICAL SUPPORT:	**Thérèse Arcand*** **Pascal Aubé** **Jean-Pierre Bérubé** **André Carpentier** **Jean-Paul Fontaine** **Carole Germain** **André St-Hilaire**
***(part-time)**	**Jean Thibault**

Photo: Claude Moffet



Temperature readings and measurement at the Duchesnay experimental site

Study LFC-45-01

EFFECTS OF AIR POLLUTION ON FORESTS (STUDY IN CONJUNCTION WITH THE NATIONAL LONG-RANGE TRANSPORT OF AIR POLLUTANTS PROGRAM - LRTAP)

Robert Boutin

Key words: soil chemistry, acid precipitation, biogeochemical cycles

*

Air pollutants carried over long distances (principally acid deposits) have the potential to alter, either directly (acting on exposed sections) or indirectly (affecting the soil), the biogeochemical cycles of forest ecosystems. Acid deposit goes on continuously and may in the long term contribute to a nutrient imbalance in forest stands.

The main objectives of this study are:

- to determine, by studying the relationships between different hydric strata (incidental precipitation, leach water, groundwater), the significant changes from one stratum to another and assess the impact on the nutrient status of the site

- to characterize the transfer of nutrients, mainly in soluble form, in various forest types (conifer stands, maple groves, etc.)

Outside associates:
B. Bernier, M. Brazeau, and C. Camiré collaborated on the biogeochemical studies in the Norbertville and Leeds maple stands and P. Arp (University of New Brunswick) assisted with models of leaching of nutrients in the Lake Laflamme watershed.

Study LFC-45-04

HARDWOOD FOREST DIEBACK (STUDY IN CONJUNCTION WITH THE NATIONAL LONG-RANGE TRANSPORT OF AIR POLLUTANTS PROGRAM - LRTAP)

Gilles Robitaille

Key words: climatic stress, acid precipitation, climate, sugar maple

*

The aim is to study the effects of natural and induced climatic stresses on the nutrient cycle and growth of sugar maple in relation to pollutants.

In the context of environmental stress, the growth of forest species in Québec may be linked to changes in the chemical and physical climate, thus the need to assess the combined effects of changes in the long-term chemical environment and the effects of cyclical variations in climate on the nutrient cycle of the tree.

To determine the effects of multiple environmental stresses on growth, we reproduce and study *in situ* climatic stresses on maples already subject to atmospheric pollution (acid precipitation).

Outside associates:
Université Laval; University of Vermont (U.S.A.); ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec; ministère de l'Environnement du Québec; MFO.

Study LFC-45-05

ANALYTICAL SUPPORT FOR PROJECT LFC-45

Alain LePage

Key words: chemical analysis, chromatography, quality control

*

The scope of the LRTAP project requires extensive sampling of biological and non-biological material. This material must be tested for a range of parameters.

The specific objectives of this study are to provide quality data to study leaders and to manage the chemical analysis laboratory.

Outside associates:
There may be exchanges of information or technology with universities, environment departments, and the MFO.

Study LFC-45-07

ACID RAIN NATIONAL EARLY WARNING SYSTEM (ARNEWS)

Denis Lachance

Key words: soil, national survey

*

The objectives are:

- to detect initial damage caused by acid rain to forest trees and soil and to determine the damage sustained by Canadian forests (trees and soil) that is not attributable to natural causes or forest management practices

- to carry out long-term monitoring of vegetation and soils so as to detect possible changes that would be attributable to acid deposits and other air pollutants in representative forest ecosystems.

Outside associates:
ARNEWS representatives (Forestry Canada, Headquarters); managers of the national FIDS databank (Petawawa National Forestry Institute, Forestry Canada); D.Maynard and I. Morrison (Forestry Canada, Northwest and Ontario regions respectively) for physical and chemical analyses of soil and vegetation.

Study LFC-45-08

MANAGEMENT OF FOREST INSECT AND DISEASE SURVEY (FIDS)

Denis Lachance

Key words: FIDS, entomology, pathology

*

This activity consists essentially in coordinating section activities with national priorities and FIDS/LFC activities with those of SPIM (MFO).

We also see that the information collected at the LFC is effectively disseminated to our provincial, national, and international clientele.

These three activities are repeated from year to year and take up an appreciable amount of person-year time.

Outside associates:
FIDS officials in other Forestry Canada regions; MFO Service de protection contre les insectes et les maladies; Peter Hall (Environmental Studies, Forestry Canada, Headquarters); I. Millers (Canada/U.S. Maple Decline Project, U.S. Forest Service, Durham, N.H.).

Study LFC-45-09

FIDS DIAGNOSIS-ENTOMOLOGY

Christian Hébert

Key words: entomology, diagnosis, insect and slide collection

*

The main purpose of this study is to provide insect diagnosis services for the FIDS section, LFC researchers, researchers and agencies outside the LFC, and occasionally to the general public.

Another purpose is to enter regional data from entomology surveys in the national FIDS databank and keep this bank up to date for Region 03.

The study also includes a facet involving technology transfer in forest entomology.

Another responsibility is to conserve the LFC insect and insect slide collection and add to it whenever possible.

Outside associates:
Staff of the Biosystematics Section, Agriculture Canada, Ottawa; Y. Maufette (Université du Québec à Montreal); E. Bauce (Department of Forestry Geomatics, Université Laval); staff of the Montreal Insectarium.

Study LFC-45-10

FIDS DIAGNOSIS-PATHOLOGY

Pierre DesRochers

Key words: mycology, pathology, fungus collection

*

This study mainly provides services, and its activities each year are quite similar, although the number of projects undertaken varies with client demand:

- identifying the main cause(s) of diseases observed in forests based on samples submitted by field technicians or other clients
- compiling and assessing the current and potential extent of the main diseases observed
- suggesting measures to eliminate or prevent damage
- providing a forest pathology information service for LFC researchers and many outside clients
- maintaining an up-to-date, comprehensive herbarium, a collection of reference cultures, and photographs of disease damage, and contributing to the national FIDS data bank located at the Petawawa Forestry Research Institute (Forestry Canada)
- conducting research on difficult identification cases or rare micro-organisms or when new problems are discovered
- collaborating with other LFC researchers on related projects

Outside associates:
Service de protection contre les insectes et maladies (MERQ); Mycology Section, Biosystematics Centre, Agriculture Canada, Ottawa; M. Dessureault and G.Bussières (Faculty of Forestry and Geomatics, Université Laval); M. Saint-Arnaud and C. Bertrans (Montréal Botanical Gardens); Steeve D'Eon (Petawawa National Forestry Institute, PNFI).

Study LFC-45-11

SPECIAL SURVEYS

Christian Hébert

Key words: entomology, pathology, surveys

*

This study involves:

- collecting information on forest insects and diseases to identify major problems in Québec
- assessing their impact on natural forests, plantations, and ornamental trees
- when problem situations arise, conducting research to identify the organisms responsible for the damage observed
- studying the biology of hitherto little-known pests
- collecting material for other forest protection projects or studies (e.g. natural control agents)
- compiling and publishing information collected in reports, journals, or other documents

Outside associates:
Service de protection contre les insectes et les maladies (SPIM) (MFO); other Forestry Canada FIDS units.

Study LFC-45-12

NORTH AMERICAN SUGAR MAPLE DECLINE PROJECT (NAMP)

Denis Lachance

Key words: dieback, pollution, tapping

*

The objectives are:

- to determine the rate of change in the condition of maples from 1988 to 1990
- to determine whether this rate of change in various levels of decline varies between:
  - pollution levels measured in moist deposits
  - tapped and untapped maples
  - different initial dieback levels
- to determine the possible causes of dieback and the geophysical relations between the causes and severity of dieback.

Outside associates:
P. Hall (Forestry Canada, Headquarters); U.S. Forestry Service (joint project); as Canadian scientific coordinator of this project, frequent contacts with provincial and federal representatives in Ontario, Québec, New Brunswick, and Nova Scotia; frequent contact with I.Miller (U.S. Forestry Service, Durham, N.H.), the American coordinator of this project.

Study LFC-45-13

CLIMATOLOGICAL CHANGES

Denis Lachance

Key words: climate changes, forest dieback, boreal forest

*

This study attempts to determine the effects of climate change on the general health and productivity of forests.

Outside associates:
A.E.S. (Atmospheric Environment Service) Climate Variability Working Group (Downsview, Ontario); H. Martin (LLO); IIASA (International Institute for Applied System Analysis): Biosphere Program, Boreal Forest Study; A.Solomon (Vienna, Austria).

Photo: Claude Moffet

Biologist at work

PROJECT LFC-81

STUDIES CONDUCTED IN CONJUNCTION WITH THE EASTERN QUEBEC ECONOMIC DEVELOPMENT PLAN

This project is composed of various studies conducted in conjunction with the activities of the Eastern Quebec Economic Development Plan (Eastern Plan).

It reflects the concerns shared by LFC researchers and professional foresters assigned to implement this program of assistance to private woodlot owners in the Lower St. Lawrence/Gaspé region.

Study LFC-81-22

FOLLOW-UP OF DRAINAGE PROJECTS IN THE LOWER ST. LAWRENCE REGION

Richard Zarnovican

Key words: yield, drainage, spruce forest

*

A five-year forest measurement study is being conducted to determine the effect of draining on the growth and timber yield of the main species in boggy black spruce forests.

Study LFC-81-23

SCIENTIFIC FOLLOW-UP OF HARDWOOD REFORESTATION: EASTERN PLAN

Claude Delisle

Key words: deciduous plantations, growth, mycorrhizae

*

Reforestation with deciduous species in the private forests of Eastern Québec is an experiment that has prompted Forestry Canada to follow the evolution of plantations more closely. In 1987 and 1988, over 300 million red ash (*Fraxinus pennsylvanica* Marsh.) were planted in the Lower St. Lawrence and Gaspé region. Experimental procedures were accordingly set up to follow development of these plantations over the four years following planting. Objectives of this follow-up were to assess the survival and growth rates of seedlings and identify factors responsible for mortality. The study should make it possible to compare plantations established on wildland and those established on harvested land. A further aim is to identify the best methods of land preparation based on those used by different landowners. A rodent control facet will test various methods of protecting seedlings. An experimental system was set up in 1989 to study the effect of an endomycorrhizing fungus (*Glomus intraradices*) on the growth and survival of red ash seedlings.

Outside associates:
This work is being carried out in collaboration with Forestry Development and R.Savard and D. Pineault (Syndicat des producteurs de bois du Bas-Saint-Laurent) as well as with the Office des producteurs de bois (La Pocatière). James-MacLaren inc., Thurso, allowed us to plant control plots on their property near Thurso. Consolidated Bathurst at Grand-Mère also provided land and sprayed with glyphosate (Roundup) in 1988 before control plots were planted.

Study LFC-81-24

EFFECTS OF CONTROLLED MYCORRHIZATION ON THE SURVIVAL AND GROWTH OF CONTAINERIZED CONIFER SEEDLINGS

Ronald Girouard and Claude Delisle

Key words: coniferous plantations, mycorrhizae, survival, growth

*

This study is primarily aimed at carrying out a five-year assessment of the mycorrhizal condition of plants artificially inoculated with the mushroom *Laccaria bicolor*. The study deals with three field-planted spruce species, black spruce (*Picea mariana*), white spruce (*Picea glauca*), and Norway spruce (*Picea abies*) grown in containers.

The second part of the study is aimed at determining the effect of the ectomycorrhizal mushroom *Laccaria bicolor* on field growth and survival of three spruce species, black spruce (*Picea mariana*), white spruce (*Picea glauca*), and Norway spruce (*Picea abies*) grown in containers.

Outside associates:
Gaspé: J.-F. Lemerle (Syndicat des producteurs de bois); C.-G. Langlois (Research and Development branch, MFO).

CHAPTER THREE

MANAGEMENT AND SERVICES

This project comprises the management of research activities as well as program administration and secretarial services. Also included are several special studies under the direct responsibility of the Director of Research.

Staff provide general direction of research activities in cooperation with project leaders, researchers, and technical support staff. The main activities involve managing the human, financial, and material resources of the Research Directorate. To do this, it is necessary to ensure that internal operations, as well as relations with other Department components and outside agencies, run smoothly. Relationships with our partners in the forestry sector are of particular importance. They require the staff of this project to represent the Research Directorate externally, to respond to various information requests, and to organize activities related to technology transfer.

DIRECTOR OF RESEARCH:	**Michel Boudoux**
ASSISTANT:	**(vacant)**
SCIENTISTS:	**Michèle Bernier-Cardou** **Wladimir Smirnoff**
PROGRAMER:	**Dominic Picard**
SECRETARIAL STAFF:	**Patricia Carroll** **Suzanne Doré** **Christine Savard**

Wladimir Smirnoff, scientist emeritus with Forestry Canada, is directly attached to the Research Directorate and is currently completing a series of studies on environmental concerns. Our statistician, Michèle Bernier-Cardou, works in close cooperation with all research projects and is responsible for such areas as the statistical conformity of research measures.

RESEARCH SUPPORT

The smooth running of the various research activities carried out at the LFC depends to a great extent on the equipment and infrastructures used. The competence of the people responsible for those facilities is the key to the success of the experiments conducted by scientists.

Project LFC-51 was set up to cover all these activities and provide researchers with the resources and training necessary for efficient operations. Most of the studies in this project are under the responsibility of technical support staff. In almost all cases, this responsibility is related to their regular work on a particular research project.

PROJECT LEADER: (vacant)

Study LFC-51-03

ANALYSIS LABORATORY

Magella Gauthier
(laboratory and analyses)
Jacques Bégin
(glassware)

*

Biological and soil analyses for various research projects.

Study LFC 50-08

GREENHOUSES

Roger Mongrain

*

Allocation of growth chambers; programing of growing conditions in the various units; management of data and monitoring of greenhouse plants; advice on the operation and improvement of equipment.

Study LFC-51-10

PROMOTION OF TECHNICAL SUPPORT STAFF

Diane Trudel and Pierre Therrien

*

Support for various information activities aimed at ensuring the promotion of technical support staff under the federal government's new classification system for technical positions.

LFC-51-11

IMAGE ANALYZER

Pierre Duval

*

The purpose of this study is to manage the TAS Plus image analyzer system and to provide technical support and assistance to users. Programing and operation of the analyzer and appropriate recommendations and instructions for each application will be developed. LFC scientific and technical staff, as well as outside organizations, can use this system to solve particular problems related to densitometric study of microscopic or macroscopic images, information on components such as number, distribution by size, surface, and other parameters that can be obtained from computer, graphic, or statistical databases. After a preliminary consultation with the study leader, requests from outside LFC should be forwarded to the Director of Research for approval.

Study LFC-51-12

GROWTH CHAMBERS

Diane Trudel and Pierre Therrien

*

Allocation of growth chambers; programing of growing conditions; management of data and monitoring of growth chamber production; advice on the operation and improvement of equipment.

Study LFC-51-20

GRAPHICS

Lucil Lepage

*

Graphics support for research personnel. This activity is now being restructured. We are in the process of developing a computer graphics unit which should be in operation by early 1992.

There are also three experimental forest stations in the Quebec region of Forestry Canada.

The Valcartier station, oldest of the three, is located near Quebec City and is used mainly for research on forest tree genetics and improvement. In addition to a nursery and greenhouses, an experimental area is used for provenance tests, progeny tests, and clone banks. The station also includes a nearby 21-hectare property on which new systems can be tested.

Some of the research on B.t. is currently being conducted at the Chute-aux-Galets station in the Saguenay-Lac-Saint-Jean region, while work at the Métis-sur-Mer station, near Rimouski, is mainly concentrated on spruce budworm. Unlike the Valcartier station, the other two are open only during the summer.

TECHNICAL SUPPORT:	**Allan Copeman** **Yvan Sénécal**
SEASONAL STAFF:	**Jean-Paul Bilodeau** **William Corrigan**

CHAPTER 4

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LIST OF ABBREVIATIONS

ARNEWS:	Acid Rain National Early Warning System
DNA:	Deoxyribonucleic acid
B.t.:	Bacillus thuringiensis
CAB:	Commonwealth Agricultural Bureau
CARTEL:	Centre d'applications et de recherches en télédétection
CERFO:	Centre d'enseignement et de recherche en foresterie de Sainte-Foy inc.
LFC:	Laurentian Forestry Centre
CPPFQ:	Centre de production de plants forestiers de Québec
CRBF:	Centre de recherche en biologie forestière
NSERC:	Natural Sciences and Engineering Research Council of Canada
ETH:	Eidgenossische Technische Hochschule (Federal Polytechnical Institute of Zurich)
GIS:	Geographic Information Service
PNFI:	Petawawa National Forestry Institute
INRA:	Institut national de la recherche agronomique (France)
JAL:	Municipalities of Saint-Juste-du-lac, Auclair, Lejeune and Lots-renversés
MERQ:	Ministère de l'Énergie et des Ressources du Québec (also MER)
MFO:	Ministère des Forêts du Québec
NAMP:	North American Maple Project
PCR:	Polymerase change reaction
FIDS:	Forest Insect and Disease Survey
SAA:	Service d'amélioration des arbres (MERQ)
ES:	Expert system
SGBD:	Système de gestion de bases de données
SOPFIM:	Société de protection des forêts contre les insectes et maladies
SPIM:	Service de protection contre les insectes et les maladies des arbres (MERQ)
LRTAP:	Long-Range Transport of Air Pollutants
UBC:	University of British Columbia
UPA:	Union des producteurs agricoles
UQAM:	Université du Québec à Montréal
NPV:	Nuclear polyhedrosis virus